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# DESIGN OF AN INTELLIGENT CAR FOR SEARCHING TRACK AND AVOIDING OBSTACLES

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***Abstract- With the rapid development of informational and intelligent technology, the mobile robot has become an important branch of robot. In this paper, through UP-InnoSTARTM robot kits for the chassis and MultiFLEXTM 2-PXA270 controller for the control core, we design an intelligent car. It uses infrared proximity sensors to detect obstacles and gray-scale sensors to search the track. And the main functions are: autonomously recognizing the trajectory, searching it steadily, making quick judgment and timely responses when meeting obstacles. In addition, a simple laboratory experiments are also proposed to illustrate the practicability of our design.***

**Index terms: Infrared proximity sensors, gray-scale sensors, an intelligent car, searching track, avoiding obstacles.**

## I. INTRODUCTION

With the rapid development of informational and intelligent technology, the application of robot is more and more extensive and it is no longer out of reach for the average people. So what is the robot? It is a kind of machine system which can independently complete a certain task through program control [1].

As well know, the technology of robot involves many disciplines, such as Industry, agriculture, medical treatment, space exploration and other fields. Facing with the knowledgable and economical opportunities and challenges in the 21st century, the robot has become one of the leading technologies of the new era, is an important symbol of a national developing level in science and economic modernization and informatization [2]. As a result, in [3] it is recognized as one of the core competitiveness in the world. Since the first industrial robot was born, it has been developed throughout the fields of machinery, electronics, metallurgy, transportation, aerospace, national defense and so on (see for example [4-6]). In recent years, the level of robot's intelligence continues to improve and changes our life rapidly. In the process of exploring and transforming the nature, manufacturing machines which can substitute for human labor has been our dreams; we refer the reader to [7]. Taking the advantages of sensing, intelligent robots have already found many civil and military applications, such as smart home [8], intelligent buildings [9], health-care [10], wild environmental monitoring [11], battle surveillance [12], etc.

At present the world developed countries such as America, Britain, France, Germany and Japan have put their robots into the education of primary and secondary schools. There have been some interesting experiments over the last ten years as attempts have been made to embody some theories from Artificial Intelligence in mobile robots [13] and it has become an important branch of robots. Through detecting and recognizing some particular signs, this kind of robot makes judgment based on these signs, and reaches the destination accurately with the fastest speed. It has been widely used in more and more occasions because of its walking flexibly, recognizing fast, positioning accurately as well as moving quickly [14].

In recent years, with the development of science and technology, there are more and more types of mobile robot's feeling sensors. An important direction of mobile robots is intelligent car and it has attracted a large number of attentions. The intelligent car is recognized as a comprehensive system combining with a set of environmental perception, planning and decision-making and other functions. At the same time, it is a typical high-tech synthesis for focusing on the use of the computer, sensing, information, communication, navigation and automatic control technology.

The aim of this paper is to design an intelligent car which can follow the track and avoid obstacles. The main functions it can realize are: autonomously recognizing the trajectory, following the trajectory steadily, making quick judgment and timely responses when meeting obstacles. The rest of this paper is organized as follows. Section 2 briefly describes the working platform and Section 3 shows the overall framework to illustrate how our intelligent car functions. In Section 4, the design and implementation of our intelligent car is presented in detail. Section 5 reports the testing results, and finally, Section 6 concludes the paper with a discussion of our future works.

## II. WORKING PLATFORM

Now the intelligent car develops rapidly out of our image, and it has substantial remarkable results from smart toys to other industries. It can be divided into three parts: sensor detecting part, execute part and the CPU. In this paper, robot to realize automatic guiding function and obstacle avoidance function must perceive the guide line and obstacles. At the same time, our design based on sensors is achieved through the UP-InnoSTARTM robot kits for the chassis, MultiFLEXTM 2-PXA270 controller for the control core and the Northstar platform to compile programs.

### a. The UP-InnoSTARTM robot

UP-InnoSTARTM robot is a suite combining with a series of spare parts package, a set of the modular robots used in higher engineering education and innovative practice. With these spare parts, we can build all kinds of innovative, unique, practical robots, and compile a robot programming for ourselves; we refer the reader to [15]. The building blocks include sensor unit, actuator unit, controller unit, the general structured parts, etc. These parts can be mutually spliced and assembled.

Because the characteristics of modularity and cordwood system, assembling as well as programming is very convenient, it is very suitable for the creating and designing all kinds of robotic models. Figure 1 shows some finished products composed by the UP - InnoSTARTM robot kits.

Figure 1. The UP - InnoSTARTM robotic products

b. The Northstar

According to the current case, the blocking reasons for the development of robotic technology popularly and massively include two aspects. On the one hand, the standard of hardware is not unified. On the other hand, different kinds of robotic manufacturers have their own independent software, which cannot be commonly used by each other. Without a uniform standard for robotic hardware, the UP-TECH co., LTD. of Beijing launches the Northstar, a graphical and interactive environment for robotic development, in order to improve the robotic software versatility, and decrease the difficulty of development.

The Working interface of Northstar is as shown in figure 2.

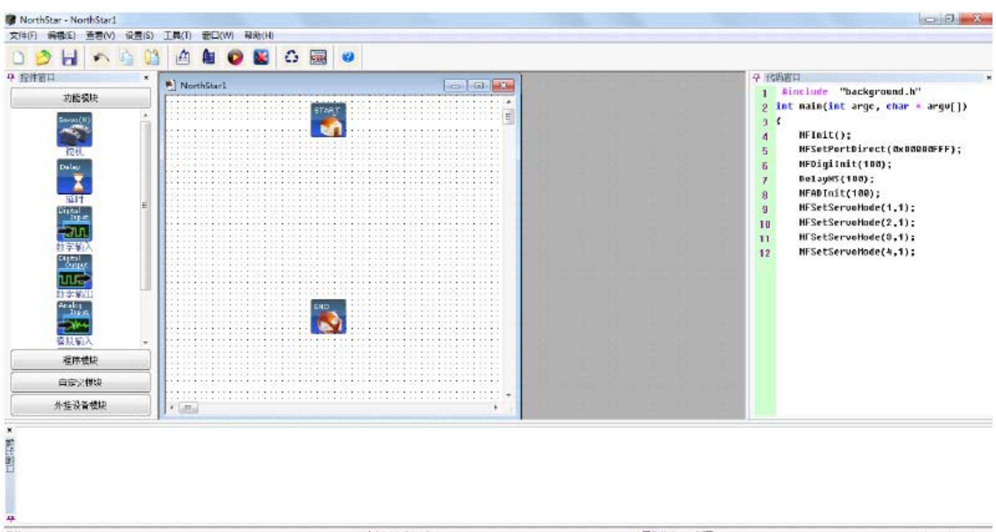


Figure 2. The Working interface of Northstar

The function of Northstar basically has the following three parts:

(1) Robot programming, using graphical and visual way, can generate simultaneously C codes;

(2) Through the background compiler, these programs will be carried out after using UP-Debugger download to the controller;

(3) The Northstar, whose function is similar to the virtual oscilloscope, can perform the real-time monitoring in the process of robot operation, and display all parts of robotic data on the PC in the form of waveform.

The Northstar platform with the traditional use of C language, JAVA language development approaches such as comparative advantage. The Northstar is a visual, graphical platform, its development speed is faster. See for example [15], ordinary users don't have to be proficient in computer language, only need to drag the corresponding modules, set their attributions, and then attach them together. The Northstar will automatically generate codes on the right side of the platform.

c. The MultiFLEXTM 2-PXA270 controller

The MultiFLEXTM 2-PXA270 controller is the core component of our intelligent car, composed of the PXA270 interface module, the AVR control card, and the PXA270 control card. It is developed on the basis of the MultiFLEX 2-AVR controller, fully supporting all functions of the MultiFLEX 2-AVR controller .It has four USB Host, a 100 bps Ethernet port, a Wifi module slot, a microphone interface, and a stereo audio output interface. In addition, it also supports a camera as a visual sensor and the microphone as acoustic sensor.

The appearance of the MultiFLEXTM 2-PXA270 controller is shown in figure 3.

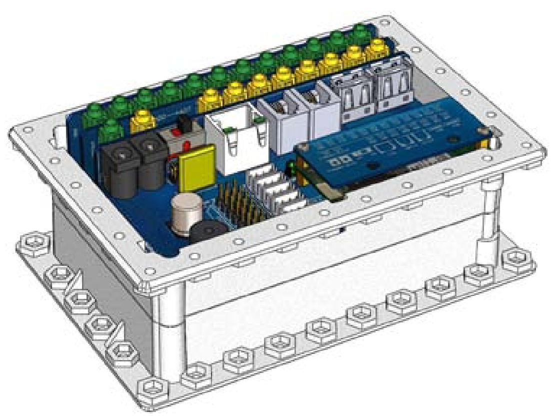

Figure 3. The MultiFLEXTM 2-PXA270 controller

## III. DESIGN THINKING

In this design, we ask for our intelligent car can realize these basic functions such as tracking and obstacle avoidance. In this section, we will first briefly present the design purpose and operating principle of our intelligent car, and then show how it functions after all.

### a. Overview about design

Robot itself is a complex system, which is an advanced technology combining with modern design, machinery, electronics, sensors, artificial intelligence, etc. The mechanical structural design of a robot is closely related to the systems of robotic control as well as driving, and the discretion of the design quality can directly affect the overall performance of a robot. As a result, the robot's mechanical structural design is basic and important part of the whole process of robot technology.

An intelligent car for searching track and avoiding obstacles is a typical wheeled robot platform, and our design in this paper is an intelligent robot set up by modular suite of UP-InnoSTARTM. Our intelligent car has the function of obstacle avoidance, which can use infrared proximity sensor to determine whether a front is disabled. At the same time, it can use gray-scale sensors for searching track.

Hence the function of the car decides that our car is mainly composed of controller, servo, debugger, and sensors. This car has four steering servos on the body, which are similar to human limbs and can accomplish specific actions; controller is similar to the human brain and control each action, what’s more it is composed of CPU, the secondary circuit and program; controller connected to the controller and PC machine, its role is to download the program to the controller; the sensor can realize judgments about corresponding function. As shown in figure 4, it is the system structure of our intelligent car.

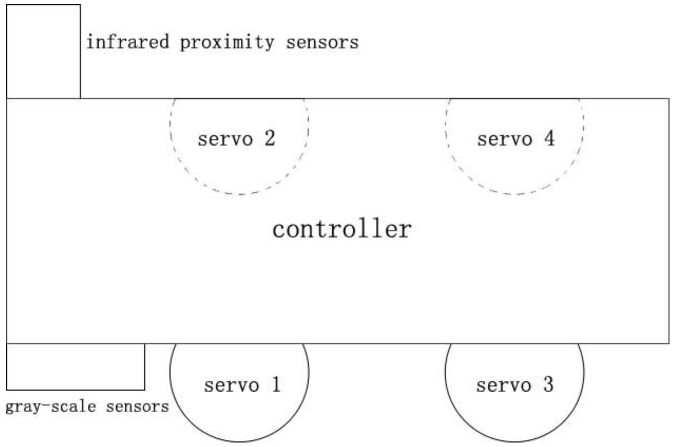


Figure 4. The system structure of our intelligent car

b. Operating principle

Figure 5 shows the operating principle of the infrared proximity sensor.

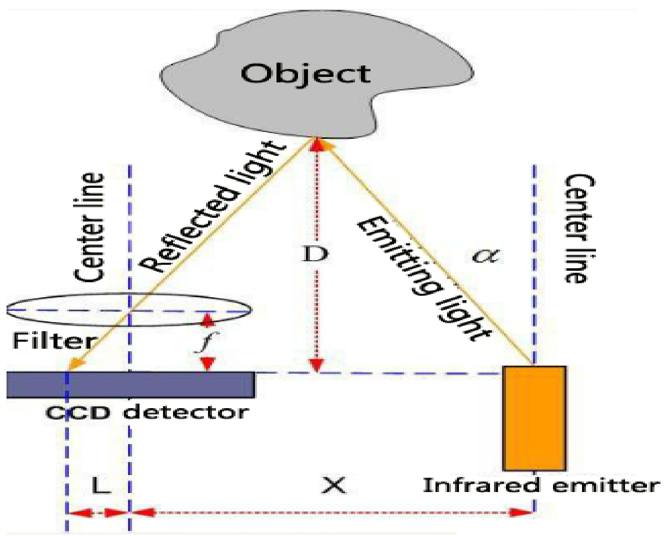


Figure 5. The principle of infrared proximity sensor

Infrared proximity sensor contains a pair of infrared signal transmitting and receiving diode, the transmitting diode launches infrared signal at a specific frequency, and the receiving diode receives this recurrent infrared signal.

From figure 5, we can see that, using the properties of reflection, given by Zhao and Zhu [16], infrared proximity sensor judges whether to close or leave by detecting the numbers of infrared energies which launched from the IRLED and reflected back from external barriers. If there is no obstacle in a certain range, infrared which has been sent decreases gradually due to the distance of propagation and finally disappears. Otherwise, infrared will be reflected to the sensor receiver. When detecting this infrared signal, the sensor can confirm that there are obstacles in front, and transmit the sign to the controller. Through a series of analysis, the controller can be able to identify changes in the environment and avoid obstacles via the coordination of the car wheels.

Infrared proximity sensor is a new kind of non-contact sensors, not affected by other light sources and the limitation of the using environment. It has the advantages of reliable operation, strong anti-interference ability, fast response, long service life etc. So the working reliability of the circuit can be greatly improved.

The so-called gray-scale can be considered to be the brightness, which may simply think as the depth of color. Figure 6 shows the operating principle of gray-scale sensor in the same system as shown in figure 5.

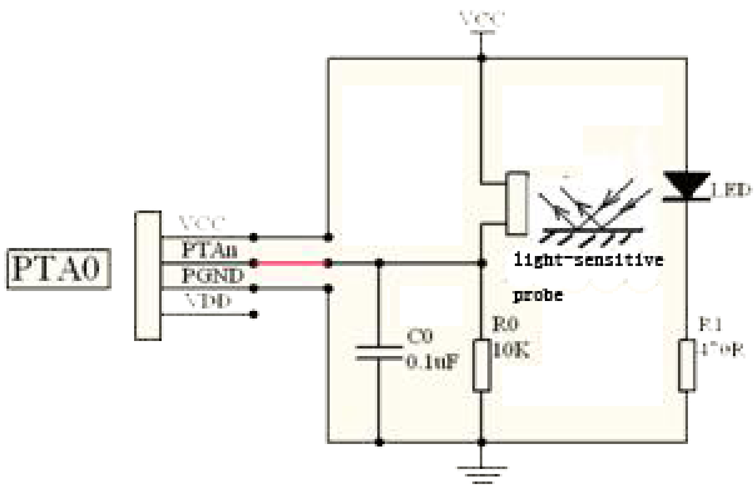


Figure 6. The principle of gray-scale sensor

The gray-scale sensor consists of two diodes, a highly luminescent diode emitting white light, the other one is the light-sensitive probe. In the effective range of detecting distance, the luminescent diode emits super-white light on the surface of inspection, then the detection surface will reflect part of the light and return to the light sensitive probe. Using that the degree of photoresistor's reflection is different in surfaces with different colors, given in [17], gray-scale sensor tests the color depth through its changes of resistance.

Due to the influence of the light intensity irradiated on the inspection surface, when the reflected light is very weak, that is to say the inspection surface is dark, the value of photosensitive diode can reach to hundreds of K Europe; the value just reaches a few K Europe under the general illumination; the value reaches dozens of europe when the reflected light is strong, that is to say the inspection surface is quite shallow. According to the intensity of the reflected light, the photosensitive diode can judge the gray level of the inspection surface. Finally the photoresistor converts it into a signal that controller can identify, so that we can detect the gray-values of the surface of detection.

Gray-scale sensors can be connected to any port of the simulation interfaces from ADC1 to ADC8. It is mainly used for testing different gray-values for different colors. For example, we can use it to judge the white line at the fire fighting games, to clear robots' position in football games, and to walk along the black line in the various track competition etc.

What kinds of sensors we use are the infrared proximity sensor and gray-scale sensor. All the above describe the principles of them.

c. Working process

Figure 7 shows the main process of our design, and from this flowchart, we may probably know how our intelligent car functions.

As we can see, after everything is ready, we press the start button, the car starts running, and automatically enters the system of initialization. When the system of initialization is completed, the car goes into the mode of searching track. That is to say that the car begins to detect the preset trajectory using gray-scale sensors, and keeps returning the gray-values between the trajectory and edge line. Once detecting some gray-value beyond the preset range, the car executes corresponding program, and the corresponding signal is sent to the controller to correct the state of the car. At the same time of following the trajectory, the car makes use of infrared proximity sensors to check whether there have obstacles ahead or not. As long as there is no obstacle, it will keep moving on. Otherwise it will perform corresponding operation to avoid obstacles. Finally after pressing the stop button, the car stops running and our operations are over. All the above can be represented by figure 7.

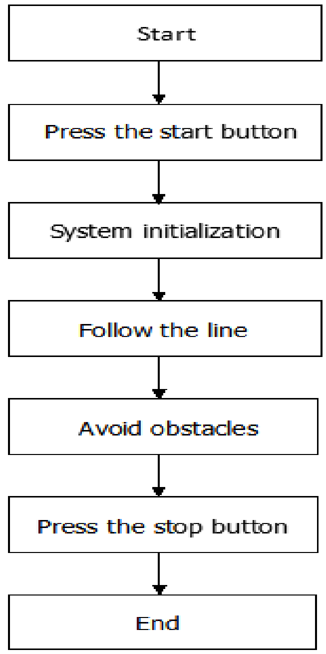


Figure 7. The main process of our design

## IV. DESIGN AND IMPLEMENTATION

### a. Design purpose

Based on the our requirements, considering that the car generally just requires a rough perception, not a clear image, so we select to use the infrared proximity sensors to detect obstacles and the gray-scale sensors to recognize the trajectory. So that our intelligent car can automatically perceive the car route, choose the correct trajectory; detect obstacles, make judgment and corresponding action, then avoid complex obstacles on the basis of following the trajectory. The circuit structure of the whole design is simple, reliable and of high performance.

### b. The required materials

According to above analysis, we list the following materials are required for this experiment：

1) One MultiFLEXTM 2-PXA270,
2) A set of UP-Debugger and lines,
3) One baseboard,
4) Some KD-Servo fittings,
5) Four servo,

6) Four rubber wheels,
7) Two infrared proximity sensors,
8) Two gray-scale sensors,
9) Some connecting-lines.

c. Hardware assembling

We need to make following operations to realize the hardware assembling.

c.i Building body

Baseboard is the largest structure of UP-InnoSTARTM robot kits, and it has a lot of symmetrical splines, which can be used to install the motor as well as structural parts, and connect various parts to a whole. At the same time, one side of our baseboard is flat, which is used to install other parts; On the other side it use the stiffener to increase the strength of baseboard. Then servo rack is used to install the structural parts of our servos. And the materials we require is as shown in figure 8.

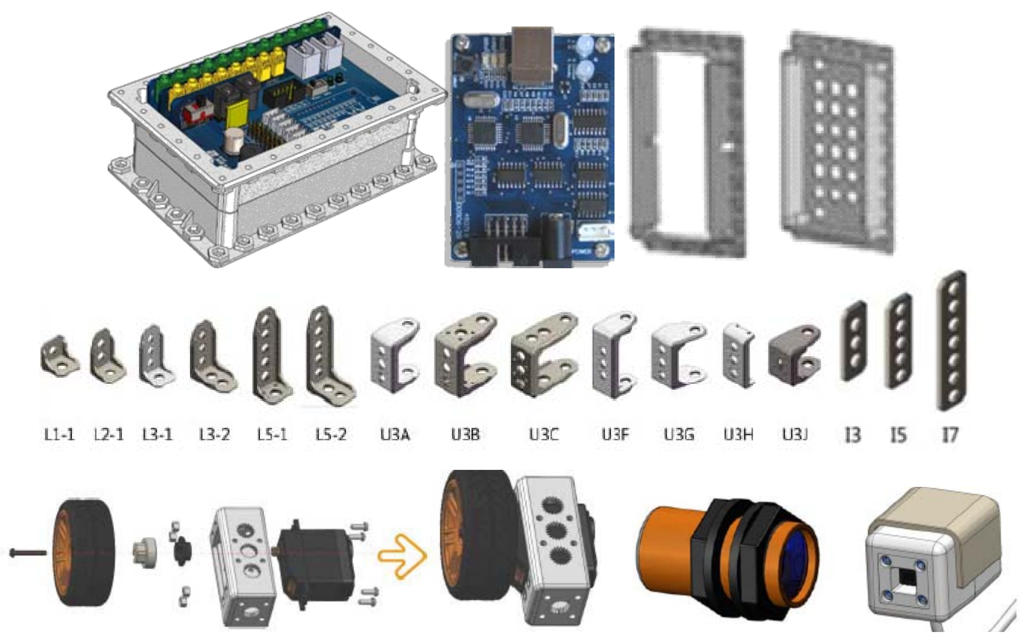


Figure 8. The required structural components

The specific steps are as follows:

Step 1: Install baseboard and servo rack. Pay attention to that its both sides are not symmetrical, and we should assemble servos according to actual situations to ensure the normal driving of wheels.

Step 2: Install servos. We fix servos into servo rack with screws.

Step 3: Install rubber wheels. Setup wheels by KD-servo fittings and fix them with screws too.

c.ii Modify the ID of servos

The default of servos' ID is 1, so we generally need to modify the values of ID before using. The specific steps are as follows:

(1) Take out multi-purpose debugger and DC power supply, connect servo of the left front wheel.

(2) Check port and open the serial port. Right click on "My Computer", choose "Management" , "Device Manager" and "Port (COM and LPT)", then we can see our port is COM4.

(3) Start RobotservoTerminal, and interface of it is as follows in figure 9:

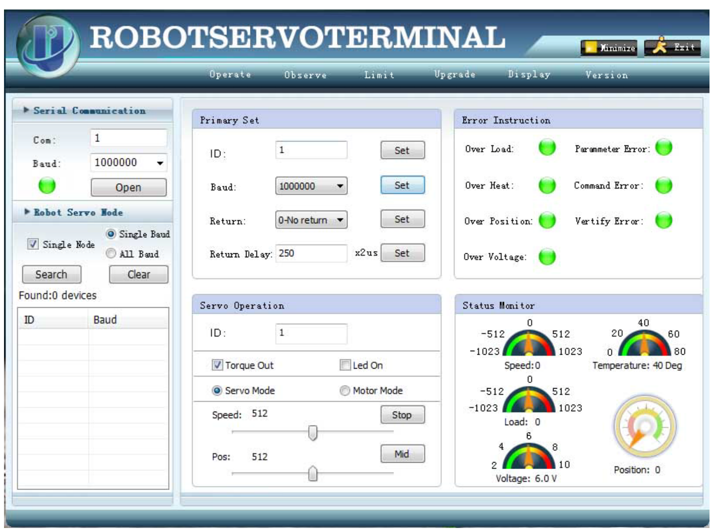


Figure 9. The interface of RobotservoTerminal

(4) Enter 4 into the input box for Com, and click the button of "Open" to open the serial port. Then the green light on the right side will turn red after successful operation.

(5) After clicking the button of "Search" to start our search, search results will appear on the right side and corresponding ID of servo as well as baud rate in the list box. Besides, the button of "Search" will become to "Stop".

(6) when scanning all nodes of servo, click the button of "Stop" to carries on the inquiry.

(7) Choose the operating servo in the list box, switch to the "Open" page operation, enter 1 into the input box for ID under "Primary Set", and modification of servo’s ID is finished after clicking the button of "Set".

(8) Change other servos, repeat above operations, and set servo’s ID of the right front wheel to 2, the left rear one to 3, the right rear one to 4.

### c.iii Wiring

Connect four servos with two-connection, and then access them into the interface of controller. Next use structural supports to fix infrared proximity sensors and gray-scale sensors and plug them into corresponding sockets. Finally, input DC regulated power supply after connecting UP-Debugger, controller and PC.

## d. Programming

### d.i Project and Servos Configuration

Open Northstar, set up a new project, click "MultiFLEXTM 2-PXA270" in the "Select Controller", and "Customized" in the "Select Robot". The interface of it is as follows in figure 10:

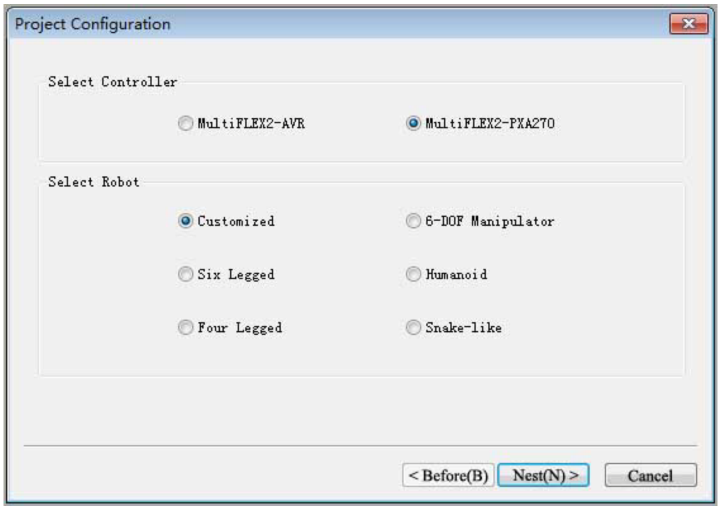


Figure 10. The interface of Project Configuration

Click "Next" button to enter the interface of "Servos Setting", fill 4 into the "Number of the current servos" and set four servos to "machine model". Then continue to click "Next" button and set AD and IO Channel. We will enter the working interface to write programs until "Finish" button. The interface of them is as follows from figure 11 to figure 13:

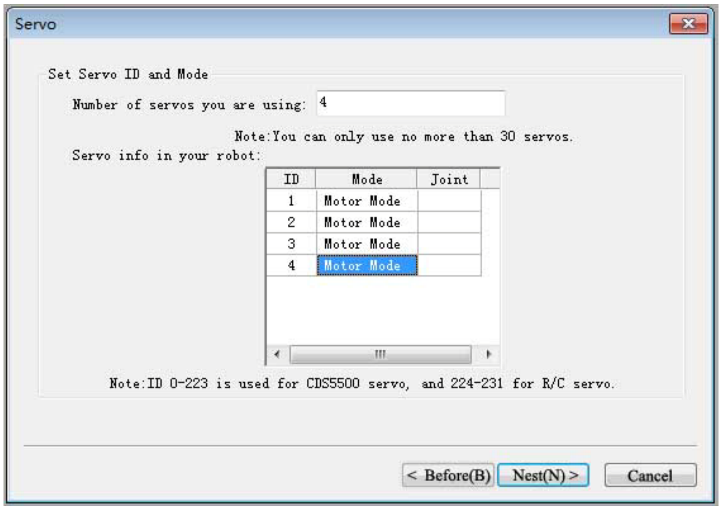


Figure 11. The interface of Servos Configuration

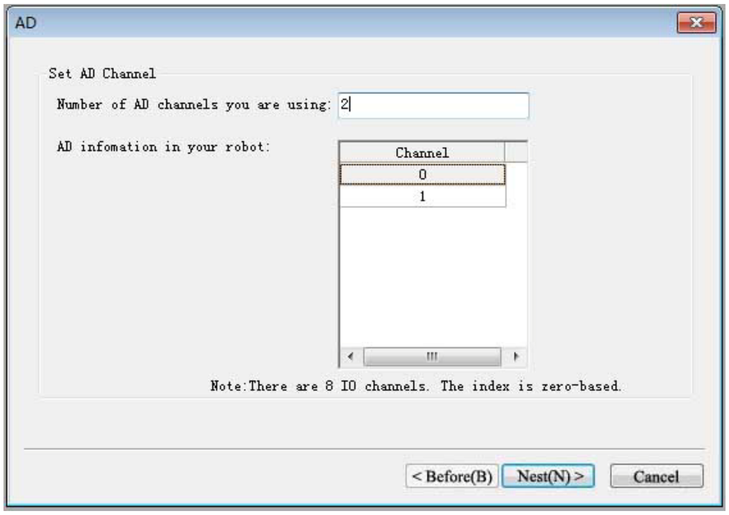


Figure 12. The interface of AD Channel

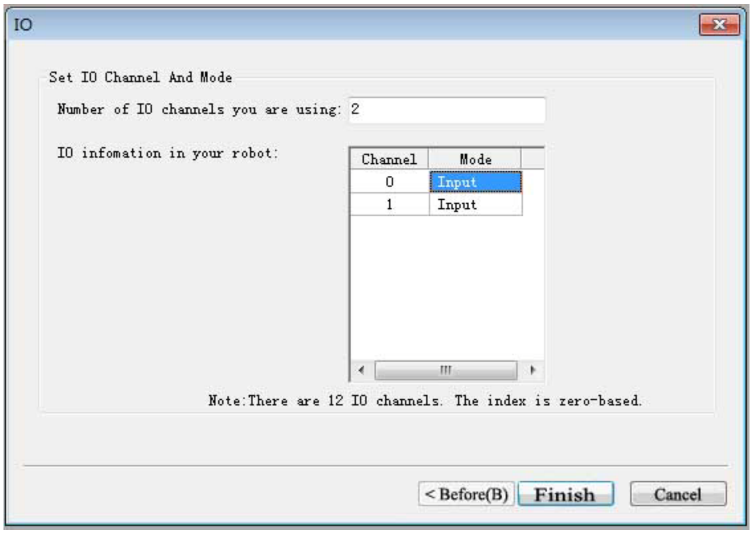


Figure 13. The interface of IO Channel

d.ii The implementation of searching track

The two gray-scale sensors are respectively arranged on the bottom of the car. The transmitter or receiver is away from the ground about 0.5 cm, and gray-scale sensors can be normally used after connecting them into the analog interface of the main control board. We control the car according to the gray-values between the trajectory and edge, so as to achieve the function of searching track. The effect picture is shown in figure 14.

Figure 14. The effect picture of gray-scale sensors

We design the working flowchart, as shown in figure 15, that the car moves forward when two gray-scale sensors detecting the trajectory at the same time. When any a sensor detected on the trajectory, the car is on the state of slightness. If the left gray-value exceeds a preset range, the controller will make instructions that wheels change the previous direction and turn to the left, otherwise the wheels to the right.

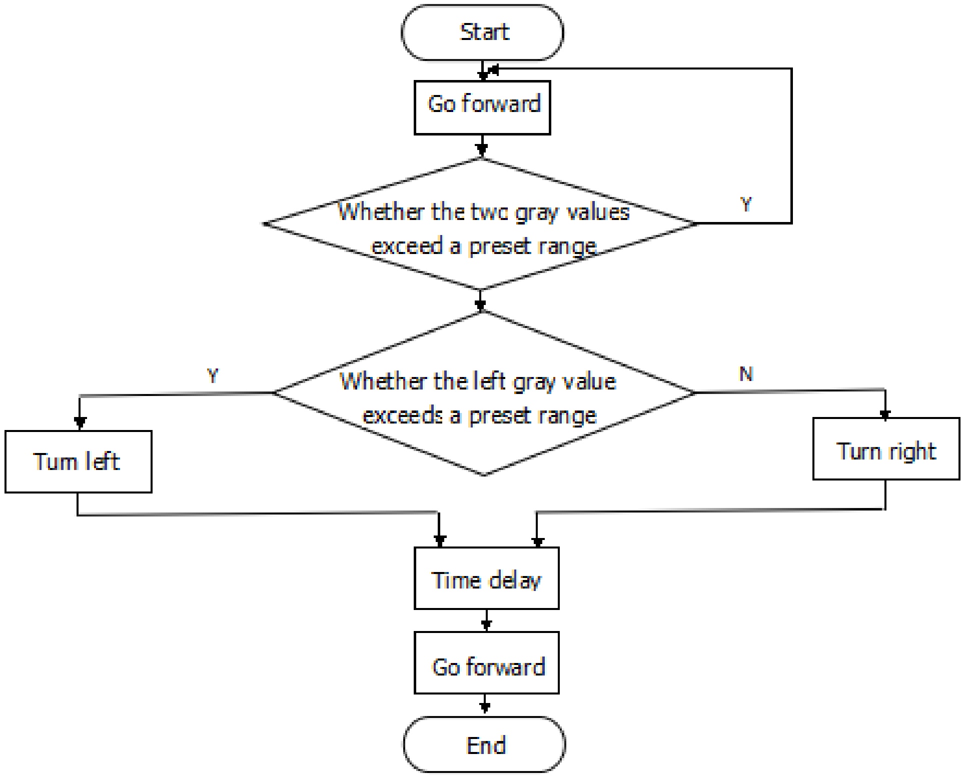


Figure 15. The working flowchart of searching track

Input two IF modules, and they are used in pairs with END IF modules. Open the dialog box of IF Widget Property and set as shown in figure 16.

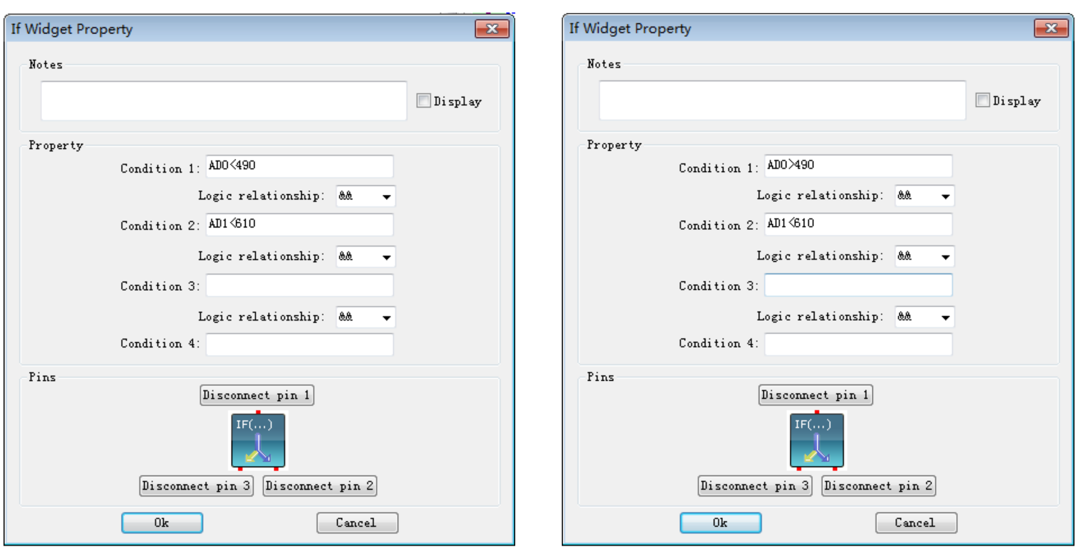


Figure 16. The setting of two IF Widget Property

At the same time, according to the working flowchart of searching track above, we designed corresponding program. The main codes are as following in figure 17:

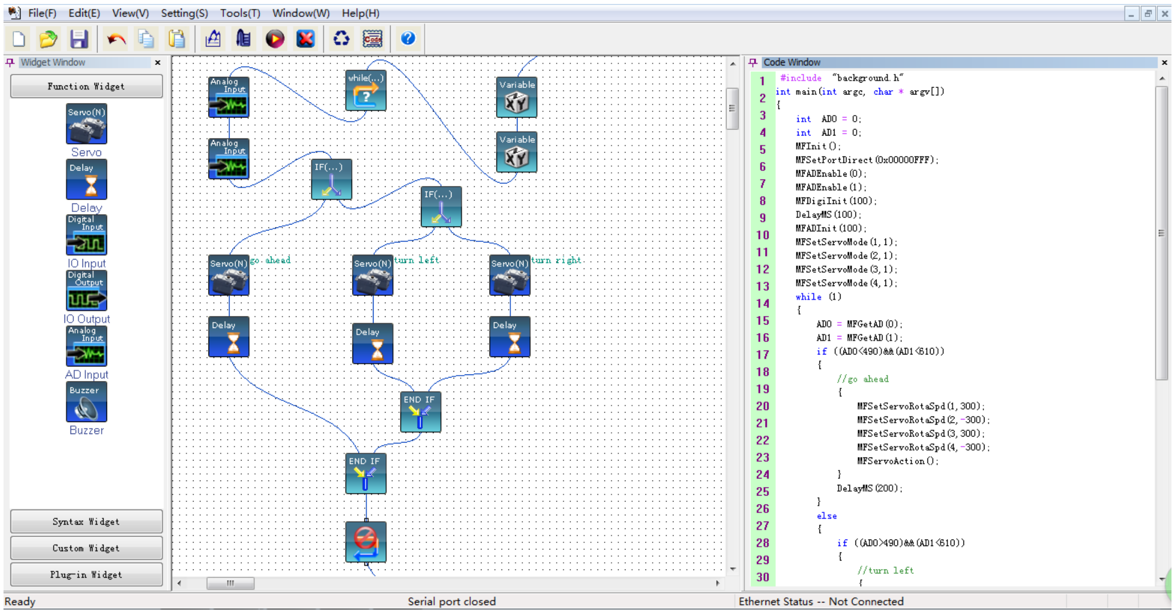


Figure 17. The main codes of searching track

d.iii The implementation of avoiding obstacles

The two infrared proximity sensors are fixed on the front of the car symmetrically. Their direction is in parallel with the moving direction. The car can accurately distinguish and make timely response according to the relative distance and orientation with obstacles, so that it can realize the function of avoiding obstacles, and we will not worry that it encounters a wall without moving back. The effect picture is shown in figure 18.

Figure 18. The effect picture of infrared proximity sensors

We design the working flowchart, as shown in figure 19, that the car goes back a certain distance and turns to the right if the left sensor detecting an obstacle; the car goes back a distance and turns to the left if the right sensor detecting an obstacle; the car goes back a distance and rotates a certain angle if the two sensors detecting obstacles at the same time. Of course, if there is no obstacle, the infrared proximity sensors have no use and the car will keep moving forward.

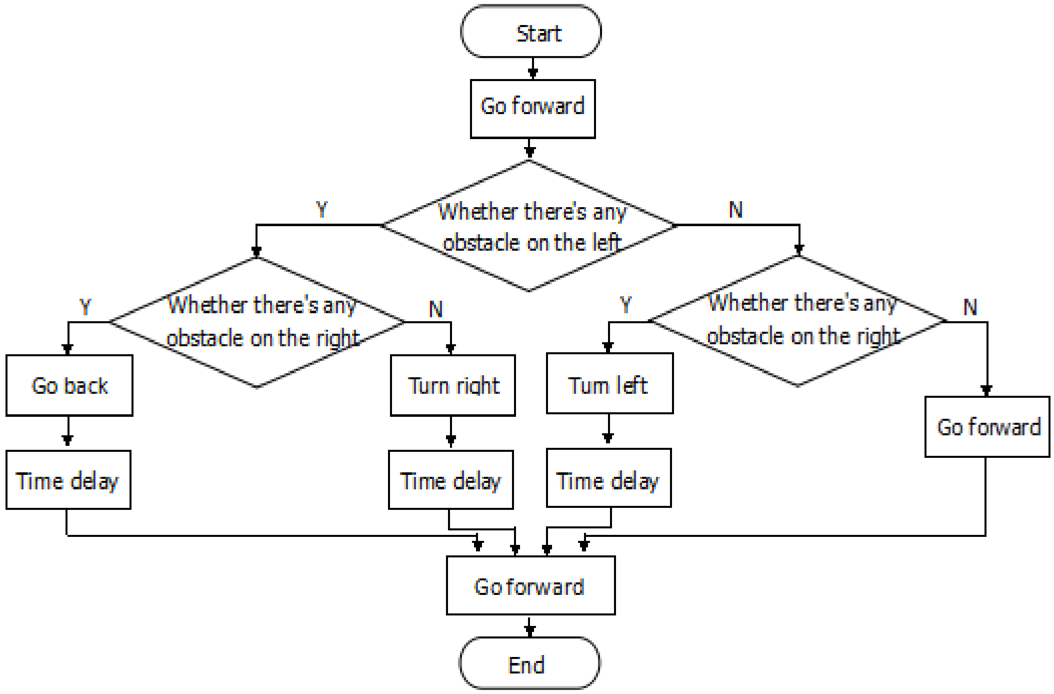


Figure 19. The working flowchart of avoiding obstacles

Input two If modules too, and we set the IF Widget Property as shown in figure 20.

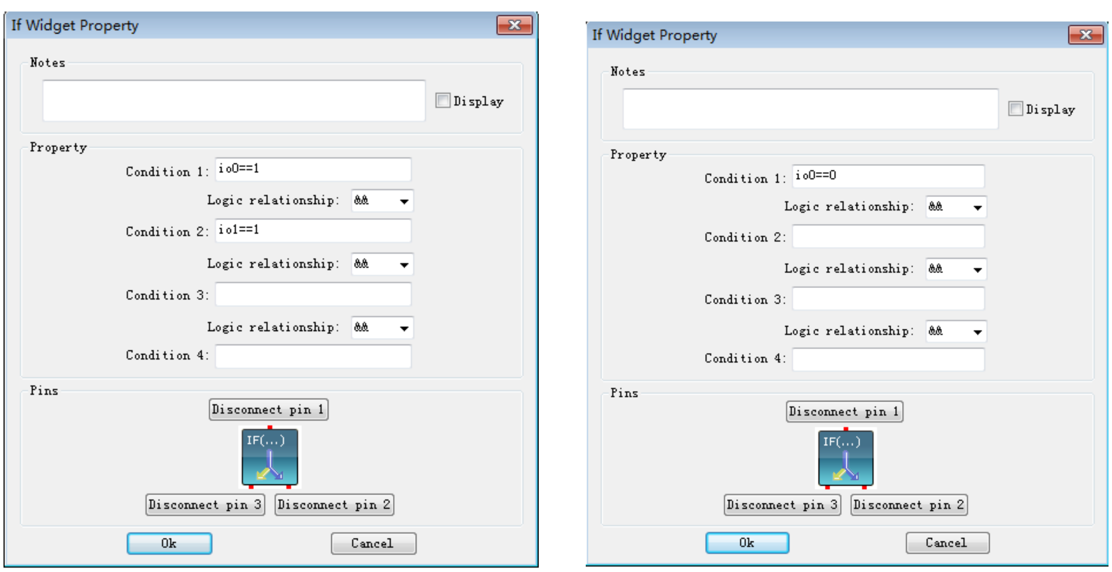


Figure 20. The setting of two IF Widget Property

According to the working flowchart of avoiding obstacles above, we designed corresponding program. The main codes are as following in figure 21:

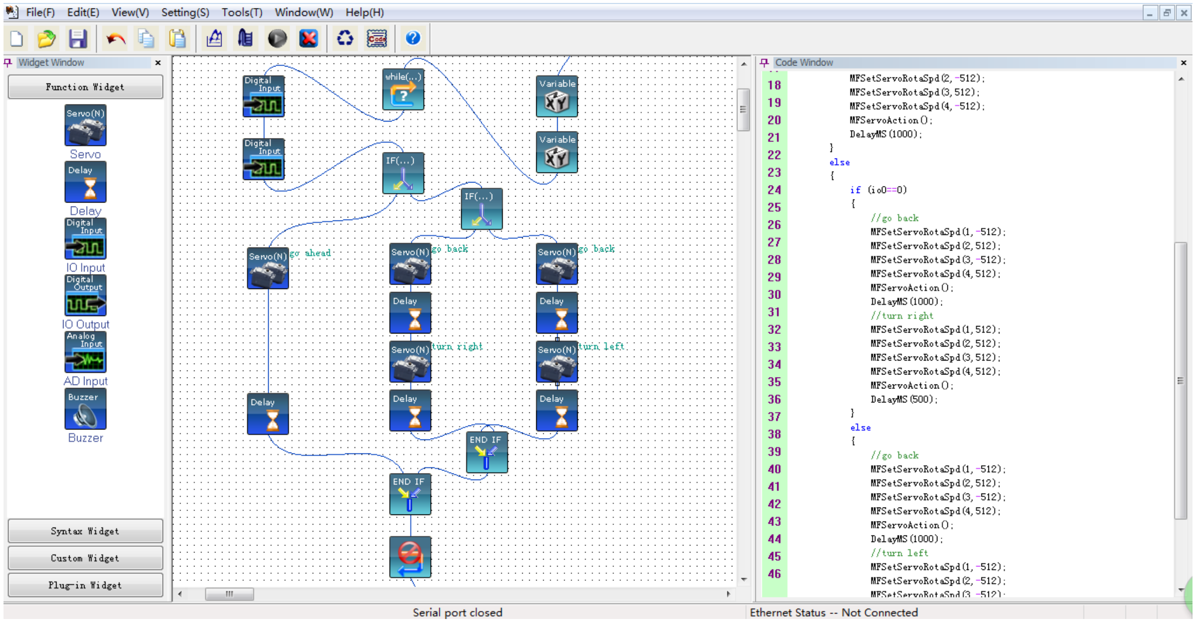


Figure 21. The main codes of avoiding obstacles

## V. TESTING RESULTS

The effect picture of our intelligent car is shown in figure 22. After finishing writing all the codes of programs, we make use of the network cable to connect the PC with the MultiFLEXTM 2-PXA270 controller, and download executable programs to the controller via FTP. In this way, the computer of user will control the controller, and the intelligent car will operate normally after resetting.

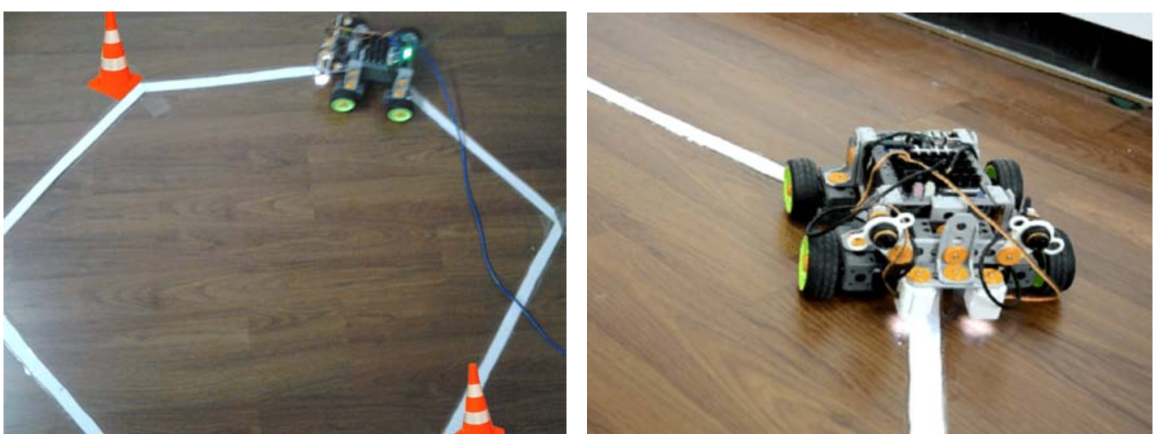

Figure 22. The effect picture of our intelligent car

a. The experimental results

After all preparations are made, we make simulated experiments on the process of searching track and avoiding obstacle. In our testing, we set the car start from the point of A to B, C, D, E, F successively, then return to the starting point and continue driving. The driving track is as shown in figure 23. In the simulation system, we use a small black box instead of our car, its track in black line, and static obstacles can be set at random during moving.

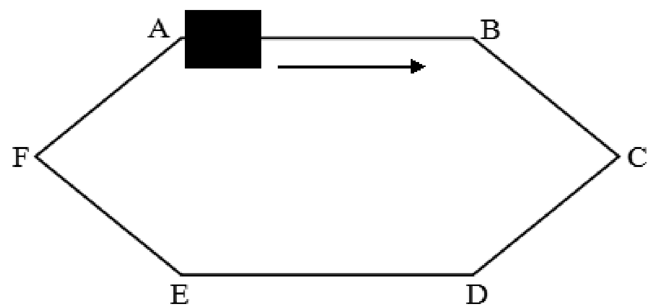


Figure 23. The driving track of our intelligent car

First of all, we test the function of searching track. We put the car on the designed trajectory in advance. By constantly experiment to adjust the car, we will compare data of deflection angle with setting trajectory, and we can get the car's tracing schematics in the preset track, which is as shown in figure 24, and we use solid line to show the preset trajectory as well as dashed line to the car tracking trajectory. From this figure we know that our car can detect automatically the predefined trajectory and achieve the function of moving along the line. However, in the process of experiment, it drives steadily on the straight line but kind of delay in the corner. This is because the controller needs time to process the return values of gray-scale sensors on both sides and make judgment in the corner.

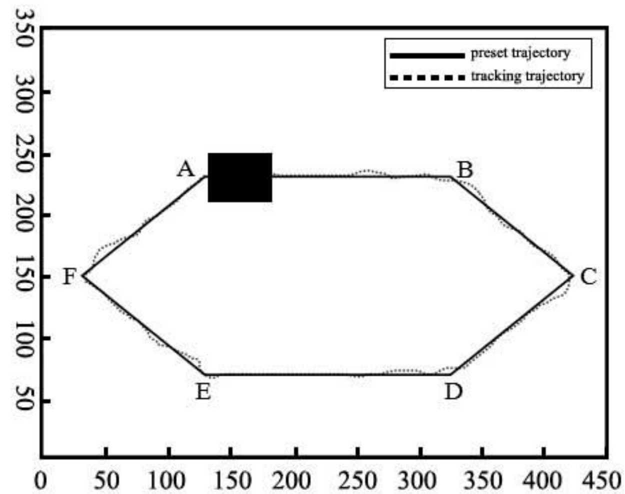


Figure 24. The testing result of searching track

Next, during the simulation experiment, we set two obstacles indicated by black circles in testing, and the trajectory that car start from the origin, avoid obstacles in turn and reach the target is as shown in figure 25. From the graphic results, we can see that the car has a strong ability of obstacle avoidance to reach the target.

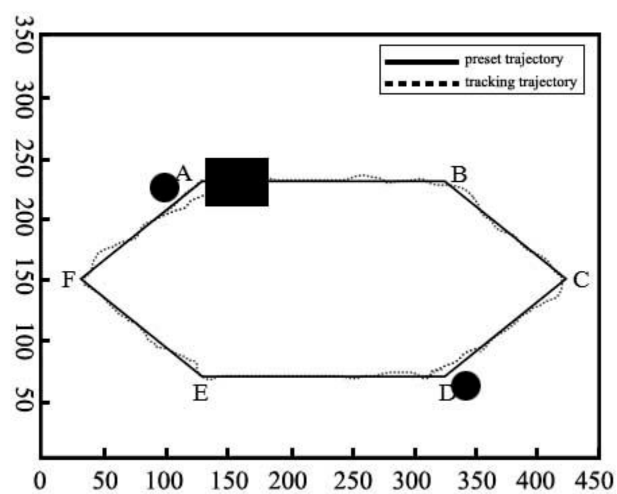


Figure 25. The testing result of avoiding obstacles

Finally, in order to effectively verify the success rates of avoiding obstacles, we perform a performance testing through changing the shape of obstacles, including the regular and irregular obstacles, as well as the height. We all test for 70 times, count the number of success and know that the shape of obstacles has nothing to do with the experimental results, while the height of obstacles are greatly influenced on it. The figure 26 shows that height below the gray-scale sensors, which is about 18.7 cm from the ground, cannot avoid obstacles.

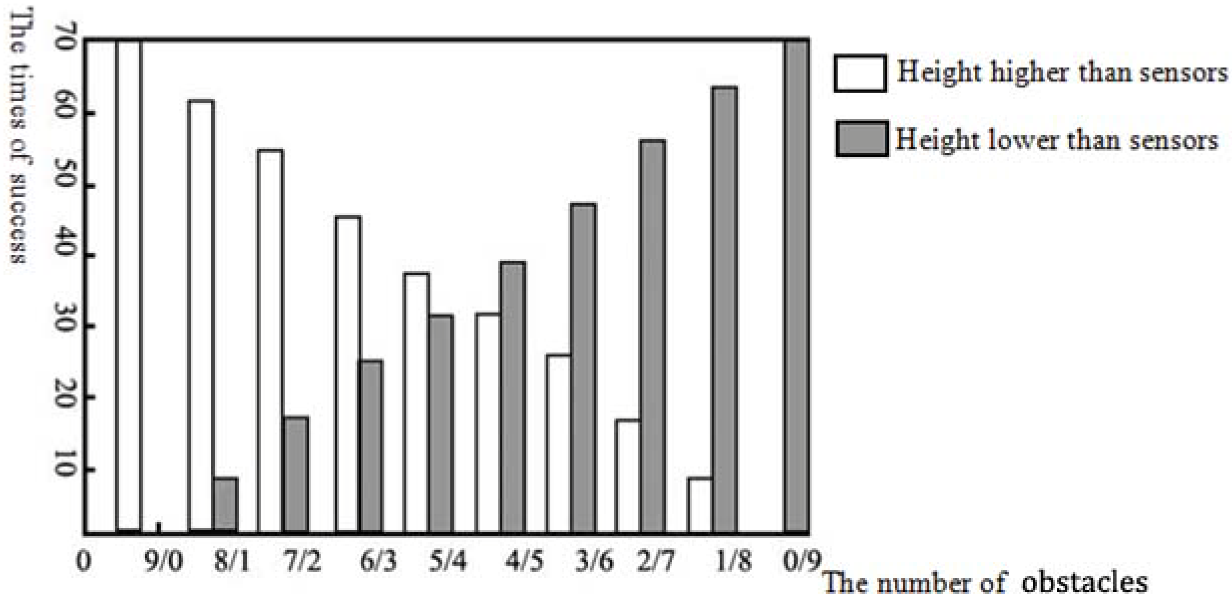


Figure 26. The success rates comparison between obstacles with different height

b. The experimental shortcoming

Intelligent car for searching track and avoiding obstacles doesn't have enough stability. Due to the strength not uniform in the process of building, the firmness of screws between each wheel and the base is different. Therefore, in the process of building, we should try our best to hold the power evenly making the stability of the car to the optimal.

In spite of this, we find that the function of avoiding obstacles is better in the process of running. This may be caused by following reasons:

Firstly, the principle of gray-scale sensor is that in [18], the color depth of detected surface is determined according to the light intensity reflected back from the detection of surface to the photosensitive probe. So the accuracy of our testing results is directly related to the distance from sensors to detected surface.

Secondly, the external light intensity has a far-reaching influence on the detecting results, see [19, 20]. So we should pay attention to avoiding the interference of external light in the process of doing experiments.

Thirdly, different materials of detected surface can also cause the difference between the return gray-values.

## VI. CONCLUSIONS

With the progress of science and technology, the concept of robotic technology gradually improves, and robotic education is becoming more and more important in school education. No matter at home and abroad, robot attracts a lot of attention. It has provided a broad space for quality education, stimulated students' interest in learning and the exploring. In addition, it provides a good platform to cultivate high-quality and creative talents.

The intelligent car which can follow the track and avoid obstacles is an important developing direction of the mobile robot. According to the requirements of our intelligent car, we read a large amount of data systematically and carefully analyzed the task’s requirement. What’s more, we also studied the working principle of gray-scale sensor and infrared proximity sensor as well as their method for application. After that, we finished the design of the intelligent car alone in the whole project.

After a hard study and hard work, we bought all the required components, and did a variety of experiments of the system, and finally made a hardware system of the whole car. Then we compile the programs combining with the project tasks and the car hardware. This system can meet our basic requirements, making the car drive along the guide line quickly and smoothly. At the same time, the circuit structure of our design is of high performance and can be widely used in real life.

In this paper, testing results have proved the reliability. Our intelligent car can autonomously recognize the trajectory, identify quickly and operate steadily.

However, because that the intelligent car for searching track and avoiding obstacles is still in the experimental stage, and the experimental conditions is limited, there are some unsatisfactory places needing to be perfected and improved, given in [21]. For example: the intelligent car based on the infrared proximity sensors is unable to complete a comprehensive informational collection of obstacles, so it cannot guarantee the shortest path of avoiding obstacles; easily affected by ambient light, the recognition speed of the intelligent car based on gray-scale sensors is slow and its running is not stable. Therefore, this design remains to be improved in the future researches.

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